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Blackfire

OR

Angular-leafspot of Tobacco

By

F. D. FROMME and S. A. WINGARD

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CONDENSED RECOMMENDATIONS FOR CONTROL

1. Select seed as far as possible from pods which are free from infection. Covering the flower stalks with paper bags is an aid in the production of non-infected pods. Old seed is less apt to be contaminated than new seed. Seed selection will help in the control of these diseases but it should be supplemented in all cases by seed disinfection.

2. Disinfect all seed by soaking them for 15 minutes in a 1-1000 solution of corrosive sublimate, then rinse in water, dry and store where they are not subject to recontamination. Treating should not be done in metal vessels and care should be taken in handling the material which is a poison.

3. The plantbed should be made up each year on new ground well removed from fields in which tobacco has been recently grown. No manure or other material which may contain refuse from a recent tobacco crop should be used on the bed. Do not use poles or boards that have been used previously in a plantbed.

4. Use new cloth for the plantbed each year. If it seems necessary to use old cloth it should be boiled thoroughly, making sure that all parts are reached by unfolding and turning it occasionally.

5. Avoid contamination of plants at transplanting time. This is especially apt to occur when neighbors help each other in pulling and setting plants. Infection may be carried on the hands, and clothing of the worker.

6. Examine the plants at transplanting time. Discard those which show infection or obtain a supply of disease-free plants from another source if possible.

7. Practice rotation in the field where practicable. If tobacco is to follow tobacco plow the stubble as soon as harvesting is finished. This will greatly lessen the possibility of carry-over in the soil.

8. Do not apply manure or other material which may contain refuse from the tobacco crop to the field.

9. Avoid working and handling the crop while the leaves are wet.

BLACKFIRE OR ANGULAR-LEAFSPOT OF TOBACCO

By F. D. Fromme and S. A. Wingard[1]

INTRODUCTION

This bulletin deals primarily with the blackfire disease of tobacco but it also includes observations and some experimental data on the wildfire disease. Both of these diseases occur commonly in Virginia tobacco fields and their presence within the past few years has constituted the most serious production hazard known in the history of tobacco culture in the State. The studies from which the data presented here are drawn have covered five growing seasons. Although information on certain phases of the problem is still wanting, it is believed that the salient features are now sufficiently well understood to point the way to successful control.

HISTORY OF BLACKFIRE

The study of blackfire was undertaken as a project of the department of plant pathology in 1917, and a preliminary report which dealt chiefly with symptoms and etiology was published by Fromme and Murray (7) in 1919. The name, angular-leafspot, was applied to the disease at this time, and the causative organism, **Bacterium angulatum**, was described as a new species. Brief directions for the control of blackfire by seed disinfection and plantbed sanitation were published by the senior author in 1920 (6).

There can be little doubt that blackfire existed prior to 1917 but there is no evidence that the specific character of the disease was recognized previously. References to similar leafspot troubles are found in non-technical literature prior to this year, and the names "firing," "rust," "blackfire," "fieldfire," "wildfire," etc., have been used rather indiscriminately by tobacco growers for a half-century or more to designate certain leaf troubles of tobacco. The tobacco leaf is especially subject to leafspot injuries. Some of these are caused by fungous and bacterial parasites, others are presumably non-parasitic or physiological. The tobacco grower has not as a rule distinguished between the different kinds of spots and, as a matter of fact, the specialist often finds it difficult to separate them with certainty. The term wildfire is often employed by the grower to include both the blackfire and the true wildfire diseases. It should properly be used to designate the specific leafspot produced by **Bacterium tabacum** as first described from North Carolina by Wolf and Foster (9), and it will be so used in this discussion. The term blackfire is less commonly used by the grower and almost invariably serves to designate the angular-leafspot disease. The spots of this disease are often quite dark in color, especially in the early stage, and since they are not always angular the name blackfire is as good for descriptive purposes as angular-leafspot. We shall, therefore, use the name blackfire in this discussion to designate the disease caused by **Bact. angulatum**

It is probably true that blackfire has occured in Virginia for a number of years prior to 1917. This is indicated by the very general and severe occurrence of the disease in Halifax County in that year, its occurrence in Campbell and

[1]Paper 57 from the department of Plant Pathology and Bacteriology.

Charlotte Counties, and reports of similar damage in the same year from other counties in the flue-cured belt. This general distribution would indicate a disease of rather long standing. There is certainly good reason to believe that blackfire has existed in Virginia for a considerable number of years: it is very probably native to the American continent and it is not improbable even that it antedates the early culture of tobacco by the colonists at Jamestown. The letters from the company in England contain a number of complaints as to the quality of the tobacco shipped by the colonists and indicate that some leaf disease must have been rather prevalent in Virginia then. An excerpt from one of the letters dated September 11, 1621 reads:

> "We are assured by our factor in Holland that except the tobacco that shall next come thence prove to be of more perfection and goodness than that was sent home last, there is no hope that itt vend at all, for albeit itt passed once yett the wary buyer will not be againe taken, so that we heartily wish that youe would make some provision for the burninge of all base and rotten stuff, and not suffer any but very good to be cured at least sent home, whereby these would certainly be more advanced in the price upon lesse in the quantity."

In a work on the history of tobacco culture published in 1875 Billings (2) gives a description of a brown rust or brown "firing" which may very possibly designate the blackfire disease. He writes in part:

> "There are two varieties of rust or "firing," brown and white; and while the former is dreaded by the grower, as it injures the quality of the plant, the other is regarded with special favor, as it gives value to the leaf. It [brown rust] spots the leaf with hard brown spots that often fall out, producing holes fatal to the value of the crop. . . . The spots vary in size; sometimes they are as large as a three cent piece, but more frequently about the size of a small pearl button. At the south rust or "firing" is much more common than in the Connecticut Valley, and often whole fields are badly affected by the malady. . . . Many theories have been advanced in regard to the cause of rust and how to prevent it. It usually occurs just before or after topping, and if the plants are ripe enough to harvest, they should be cut before the rust spreads to any great extent. It makes its appearance very suddenly, and if the weather be favorable (damp), spreads rapidly, often in a few days injuring the plants to a great extent."

A brief reference to fieldfire is made in a bulletin (1) of the Virginia Agricultural Experiment Station issued in 1892 with the observation that the trouble was less severe on plants which received dried blood and nitrate of soda than on those which received sulphate of ammonia or no fertilizer.

RANGE OF BLACKFIRE

At the present time there is no locality in the State where tobacco is grown in which blackfire does not occur; it is practically coextensive with the culture of tobacco in Virginia. This very general distribution was shown by a survey which was made in all section of the State in 1920. Tobacco crops on 74 farms were inspected and 63, or 85 per cent, were found to be affected with blackfire. Subsequent to the first report of the disease from Virginia it has also been reported from the following States: North Caolina, South Carolina, Georgia, Kentucky, Tennessee and Indiana. A leafspot which is probably identical with blackfire has also been reported from Ohio, Pennsylvania and Maryland. Since the pathogene is seed-borne there have, no doubt, been opportunities for introduction into most section of the United States where tobacco is grown and possibly also into other countries. We have recently received specimens of a leafspot of tobacco from Rhodesia which is much like blackfire in appearance.

While it is evident that blackfire is not a disease of recent introduction in Virginia it seems to be true that it has been more generally destructive within the past few years than at any time in its previous history. This is possibly to be explained by a combination of several years which were unusually favorable for the development of the disease and the consequent increase in numbers of the pathogene, and also by the increase in acreage devoted to tobacco culture. The intensive production of any crop naturally tends to increase the facilities for the spread of its parasites.

NATURE OF LOSSES

The several epidemics of blackfire within the past few years have occasioned great alarm among tobacco growers and have resulted in very severe losses. There have been three epidemic years, 1917, 1919 and 1920, within the past five years, of which that of 1920 was most general and destructive. Local epidemics occurred in 1918 and losses in 1921 were very slight as a rule.

Accurate estimates of losses from blackfire are not easily made since reductions in both yield and grade are involved. The leaf loses weight through the death of tissue and the market value is greatly lowered by the reduction in quality or grade. Data secured from the 1917 crop of the substation in Charlotte County (7) indicated a loss in yield of 20 per cent and a reduction in grade of 40 per cent. Many farmers have experienced losses equally or more severe. An analysis of the production data for 1920 shows a shrinkage in the Viginia crop of 21,853,000 pounds during the month of August. The condition on August 1 was 100 per cent with an estimated production of 199,243,000 pounds but the excessive rainfall from August 15 to September 5 brought on a severe epidemic of blackfire and wildfire and the estimated production at harvest was only 177,390,000 pounds, a shrinkage of 11 per cent. The loss in quality, which was reflected in the low average price of tobacco of that season, was probably greater than the loss in yield. That the greater part of the damage in 1920 was due to blackfire is shown by our survey records, blackfire being found in 85 per cent of the fields inspected while wildfire was only found in 17 per cent. Blackfire was present in all fields where wildfire occurred, sometimes one and sometimes the other being most prevalent. The distribution of the two diseases would indicate that about 80 per cent of the loss in the State as a whole was caused by blackfire and about 20 per cent by wildfire. At the average price for the crop of 1920 of 24 cents, the loss of 21,853,000 pounds would amount to $5,244,720. This figure would probably be doubled if the loss due to reduction in grade were added.

SYMPTOMS OF BLACKFIRE AND OTHER LEAFSPOTS

The blackfire organism, so far as is known, does not attack any plant other than tobacco. Attempts to inoculate tomato, potato and pokeweed (**Phytolacca decandra**) have given negative results, and these and other cultivated and wild plants in the vicinity of tobacco plantbeds and fields have been repeatedly examined for evidences of the disease, but none has been found. There has at no time been any evidence to indicate that an additional host was responsible for overwintering of the disease or played any part in the spread of infection. Additional tests should be made, however, especially on wild solanaceous plants. It is to be noted that Chapman and Anderson (3) have recently infected petunia, eggplant, pokeweed and tomato with the wildfire organism, and that Wolf and Foster (9) have found it to be slightly parasitic in injured tissue of cowpea leaves.

The blackfire spots occur on the leaves and flower parts; no infections have been found on the stems. They are found on the leaves of seedlings in the plantbed as well as on leaves of growing plants in the field.

Symptoms on Seedlings in the Plantbed

The very general occurrence of blackfire on seedlings is shown by the surveys of plantbeds made in 1919, 1920 and 1921. The surveys of the first two years were made in Charlotte County while that of the third year included a number of additional counties. The occurrence of blackfire and wildfire in the inspected plantbeds is shown in table I. Blackfire alone was found in 82 of the 142 beds inspected, wildfire alone in 2 beds, wildfire and blackfire together in 17 beds, and 41 beds (30 per cent) were free from both diseases. Blackfire was found separately or in combination with wildfire in 99 beds and wildfire alone or in combination in 19 beds. The close agreement between the incidence of the two diseases in the plantbed and field surveys is noteworthy. Blackfire was found in 85 per cent of the fields and in 70 per cent of the plantbeds, wildfire in 17 per cent of fields and in 13 per cent of plantbeds.

Table I.—*Occurrence of blackfire and wildfire in tobacco plantbeds in Virginia.*

Year	No. beds inspected	Disease free	Blackfire only	Wildfire only	Blackfire and Wildfire
1919	17	4	7	2	4
1920	29	5	21	0	3
1921	96	32	54	0	10
Total	142	41	82	2	17

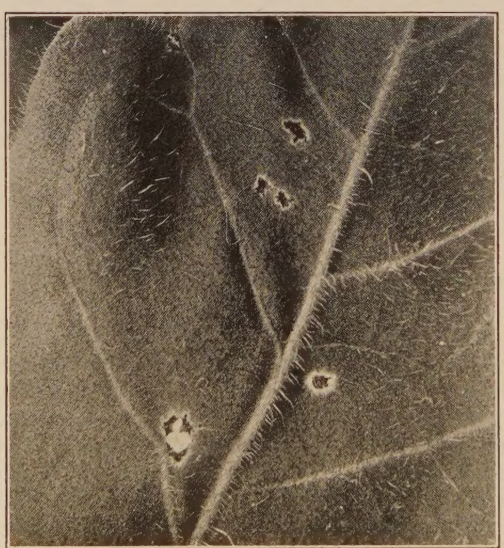

Figure 1.—Blackfire spots on a seedling leaf of tobacco as seen in transmitted light. The spots are angular and are bordered by a clear, narrow zone. About 2x.

The severity of infection in plantbeds varies greatly. In a small percentage of beds infection is found on practically every plant; in many others only a few infected plants are found. In these cases infection is apt to be localized within certain areas in the bed. Blackfire is especially apt to be found in those areas in the bed where the plants have made the most vigorous growth, and the infection is most readily seen when the seedlings have reached the size for transplanting. As a rule only two or three spots are found on the seedling leaf but large numbers are occasionally seen.

Blackfire spots on the seedling leaves are very much smaller than the mature spots on the leaves of the field plant, which are quite similar in appearance when young but enlarge greatly. The seedling leafspots remain small and never approximate the mature field leafspots in size or appearance. As a rule they are quite angular or irregular in shape; in color they are black or very dark brown. A very characteristic feature, one which invariably permits a positive diagnosis, is found in the narrow, clear zone, on the margin of the spot which is seen when the leaf is held to the light. This feature is well sown in figure I. The tissue in the center of the spot often cracks and drops out (figures I and 2) and a severely infected leaf may be greatly deformed by the uneven growth of diseased and healthy parts as shown in figure 3. The spots are often more numerous on one side of the midrib and they are equally prominent on the upper and lower surfaces. They are especially apt to occur on the margin of the leaf a short distance back from the tip. The margin is puckered at the point of infection as seen in figure 2. We have found blackfire infection most readily in our plantbed studies by looking first for leaves with puckered margins in those areas where the plants are most vigorous. This feature is of value in determining presence or absence of infection in plantbeds having only a small percentage of infected plants.

Figure 2.—Blackfire spot on a seedling leaf of tobacco. Infection occurs commonly near the leaf margin a short distance from the tip. The puckered leaf margin is characteristic. About 2x.

Figure 3.—A seedling leaf which shows numerous blackfire infections. The ragged appearance is caused by the falling out of affected tissue. About natural size

Figure 4.—A wildfire spot in the early stage of development on a seedling leaf of tobacco. The small dark center is surrounded by a broad pale halo. About natural size.

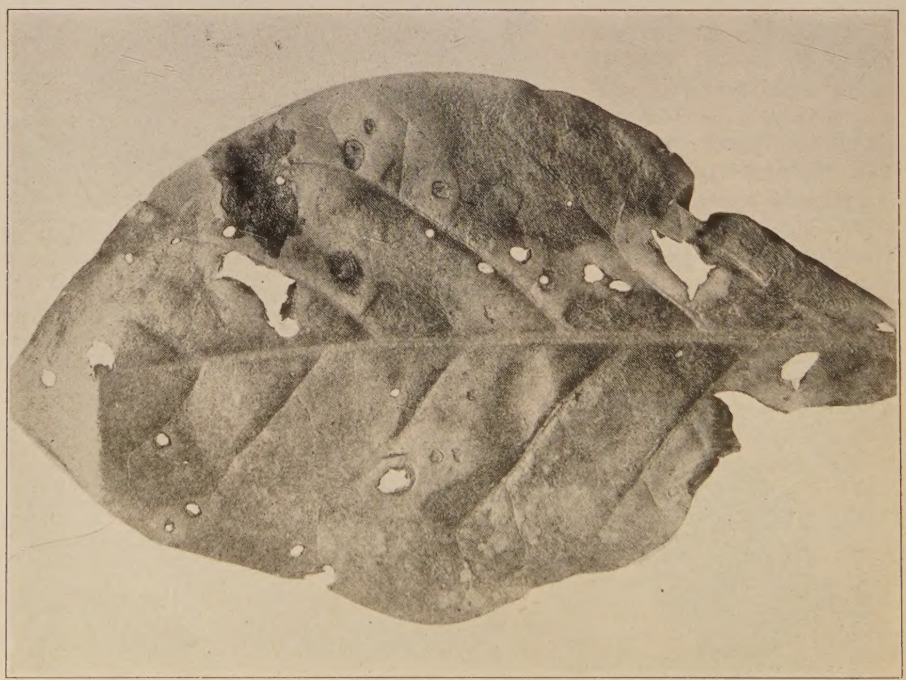

Figure 5.—A seedling tobacco leaf showing numerous wildfire lesions. The centers of the older spots have fallen out. About natural size.

The two other leafspots which occur in tobacco plantbeds in Virginia are rather easily distinguished from blackfire. The wildfire seedling-leafspot is quite similar to the field-leafspot. It is characterized in the early stage by a small, brown center surrounded by a broad yellow, or pale green halo which usually forms an almost perfect circle. The brown center enlarges and may drop out leaving a shot-hole appearance. Typical wildfire spots on seedling leaves are shown in figures 4 and 5.

Figure 6.—A fungous leafspot which is common in tobacco plantbeds. Numerous pycnidia may be seen in the center of the larger spot. About 2½x.

A third leafspot, which is very common, has often been mistaken for wildfire by tobacco growers. This spot has apparently not been described previously. We have seen it in a great many plantbeds particularly where the plants show lack of vigor. It has been found only on seedlings and apparently does not persist or increase on the plants after they have been set in the field. This spot is caused by a fungus, a species of Phyllosticta or possibly of Phomopsis. It is characterized by the presence of pycnidia which appear in the centers of the older spots, and which are seen as small dots in figure 6. The spots are found commonly on the leaf margins or tips but may also occur in the central part of the leaf. They are circular or elliptical in outline and the mature spot averages about 1 cm. in diameter. The color of the spot ranges from light tan to brown and in mature spots the tissue becomes very thin and papery and almost transparent. The tissue tears easily and often falls out. Numerous pycnidia are found in the central region of the older spots. These are honey-yellow in color at first and become brown with age. The

brown leaf veins of the diseased tissue stand out prominently. The margin of the spot is usually quite definite and is marked by a thin dark line which may diffuse out into a water-soaked appearance in some cases. The spot is often bordered by yellowed tissue but the halo is never as definitely marked as in wildfire. In early stages the spot appears as a dull grey-green or brown area which is darker in color than the leaf. A wet rot of the tissue sometimes occurs and may involve a consider-

Figure 7.—Seedling leaves affected with fungous leafspots and the wet-rot which often follows. Slightly reduced.

able portion of the leaf as is shown on the left-hand leaf in figure 7. The very young spot may be mistaken for blackfire but it never shows the clear line which is seen on the border of the blackfire spot in transmitted light.

Symptoms on Plants in the Field

Infection of Leaves

In their original description of blackfire, the angular character of the spot was stressed by Fromme and Murray, and the name angular-leafspot was used for the disease. The writers have since found that the spot is not invariably angular, in fact it may be quite rounded in outline under certain conditions. This is true chiefly of dark tobacco where the leaf is thick. On thin-leaved, bright tobacco from which the original description was drawn the blackfire spot is typically angular. Valleau (12) has also found this to be true of blackfire in Kentucky. He writes: "On black tobacco the angular-leafspots are often much larger than on Burley tobacco and are generally not angular. Spots which were determined definite-

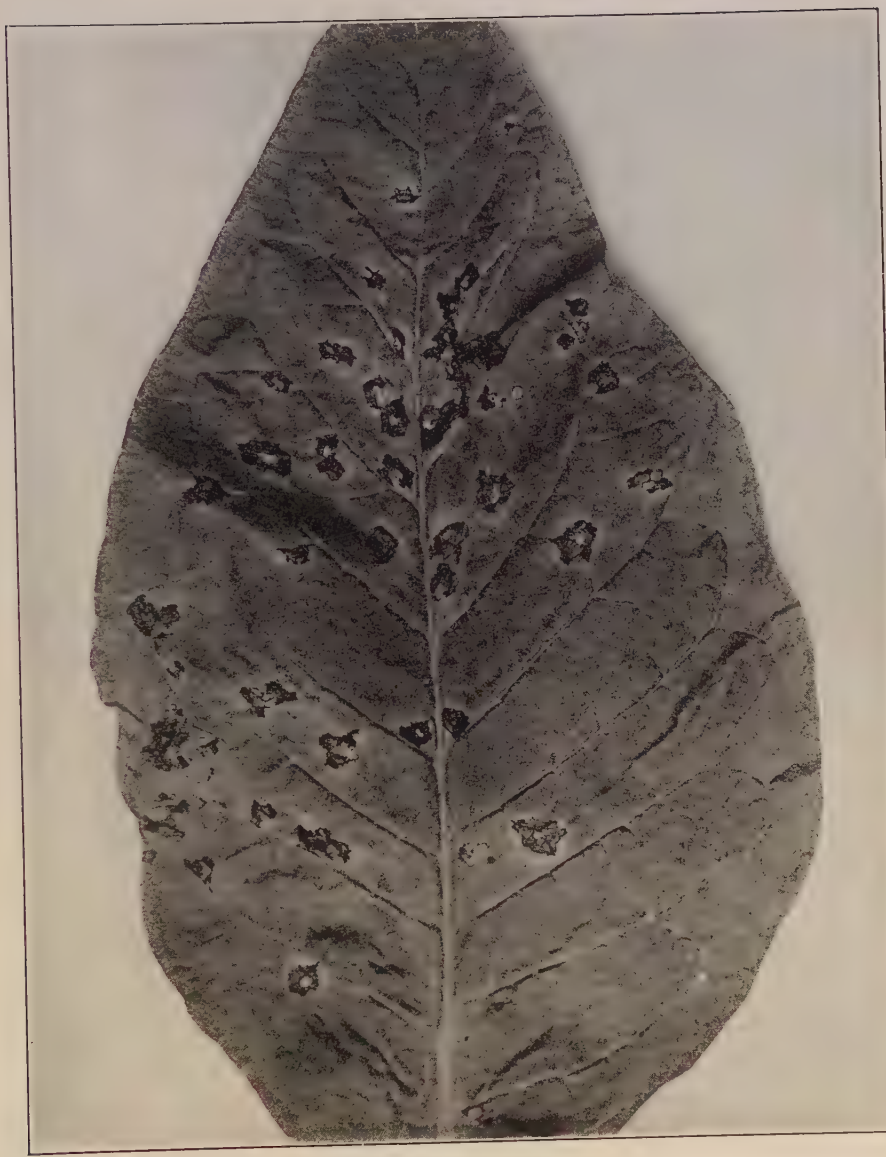

Figure 8.—A field leaf of tobacco damaged by blackfire. About one-third natural size.

ly to be angular-leafspots have been seen which were over one inch in diameter.' This statement is confirmed by our observations. The spot of bright tobacco in Virginia is angular and rarely exceeds 1 cm. in diameter, but the spot on heavy, dark tobacco is commonly not angular and is considerably larger than the angular type of spot as a rule. This difference in shape is seen in a comparison between figure 9 and plate I. The zonation in the spot on dark tobacco is also more con

spicuous than that on bright tobacco. The color of the spots varies considerably from tan to a dark-brown, young spots may be almost black. The border is usually darker in color and is quite definite, and a small, dark center is commonly seen. The leaf tissue bordering the spots is yellowed, but this diffuses into the normal green color and never forms a sharply defined halo as is found in wildfire (plate II) The blackfire spots are found scattered over the surface of the leaf but are frequently more numerous on one side of the midrib than on the other. They are often so numerous that they coalesce and a large area of the leaf may be destroyed in this way (see figure 8). The centers often drop out and in cases of very severe

Figure 9.—Blackfire spots on a thick leaf of dark tobacco. The spots are less angular and the zonations more prominent than those found on bright tobacco. About 2x.

infection little more than a skeleton of the veins may be left. The margins of heavily infected leaves roll downward and the leaves may be considerably deformed due to unequal growth of the infected and healthy parts. These features are well shown in figure 10, which illustrates a severe case of blackfire in the field. Under some conditions the spots become blanched with age and are almost white in color.

Wildfire spots are easily distinguished from those of blackfire in the early stages. They begin as round, pale-green or yellow spots which are sharply differentiated from the normal green tissue of the leaf. A brown center soon develops within the spot and this enlarges until most or all of the tissue which composed the original yellow spot is involved. The young wildfire spot on the seedling leaf shown in figure 4 is also typical of the appearance of the young spots in the field. Most of the spots in plate II show a later stage of development. A narrow halo usually remains on the border of the mature spot but this is not always evident. It

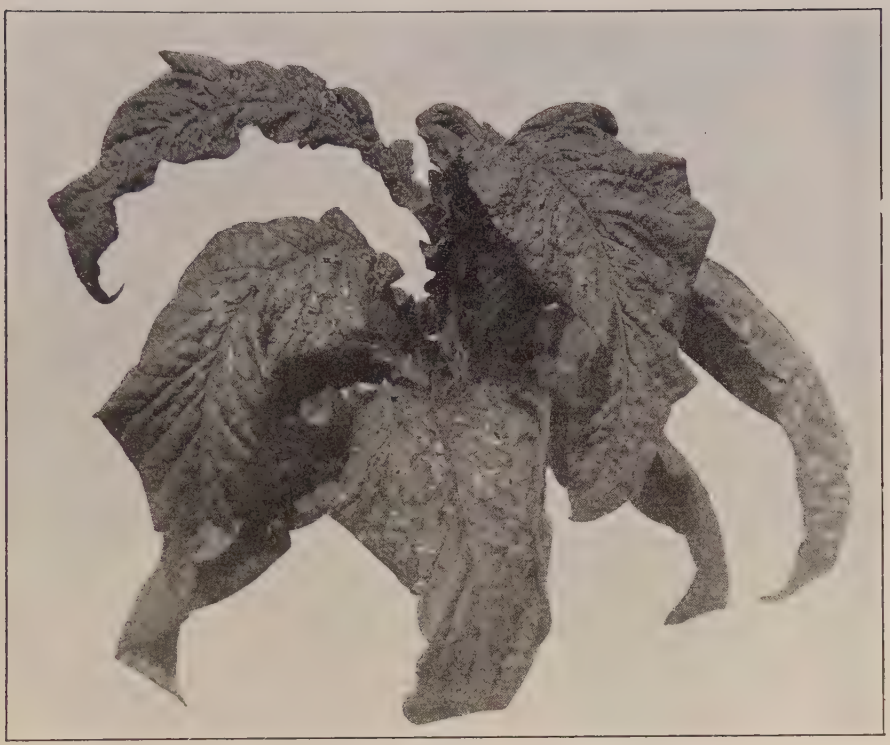

Figure 10.—A plant of Lizard Tail showing inrolling and distortion of the leaves, due to severe blackfire infection.

is often not an easy matter to distinguish the mature wildfire and blackfire spots, but young spots are usually present on some leaves of the plant and these are easily separated. It is not unusual to find both wildfire and blackfire on the same plants.

A third type of spot occurred rather commonly in tobacco fields during the very dry season of 1921 and was often mistaken by farmers for blackfire or wildfire. This spot is illustrated in figures 11 and 12. It is very evident from the location of the spots with reference to leaf margins and veins that this condition is due primarily to dry weather. We will refer to it as drought-spot. The spots are restricted to the tissue between the larger veins and to the leaf margins which are usually rolled downward. The spots are roughly circular or more commonly are irregularly lobed. They frequently coalesce as shown in figure 12. They vary greatly in size from about 5 to 20 mm. in diameter and average about 15 mm. The spots are brown in color, the margins being definite and marked by a darker line, and are bordered by a yellow zone which diffuses into the normal green of the leaf. Drought-spot is evidently brought about by a lack of balance in the water supply within the plant. Under very dry soil conditions, such as obtained generally during the summer of 1921, the quantity of water given off in transpiration is apt to exceed the amount taken in by the roots. The tissue farthest from the principal veins is especially apt to suffer from lack of water and death of groups of cells on the leaf margins and between veins results. In appearance

drought-spot is suggestive of the condition known as potash hunger, the spots of the latter trouble occur particularly at the tips of the leaves and they are not so definite in outline as drought-spot.

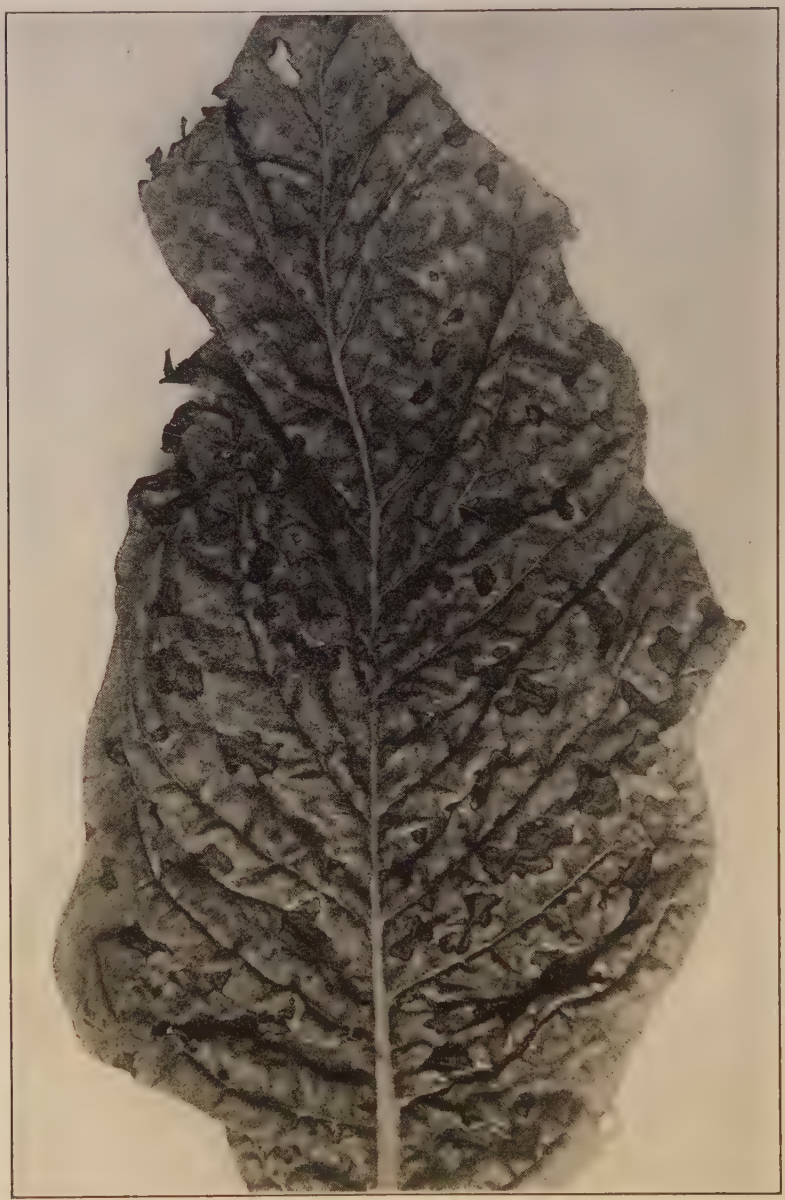

Figure 11.—A tobacco leaf affected by drought-spot.

A fourth type of leafspot occurs rather commonly in Virginia tobacco fields but usually only a small percentage of plants are affected. The spots are small and

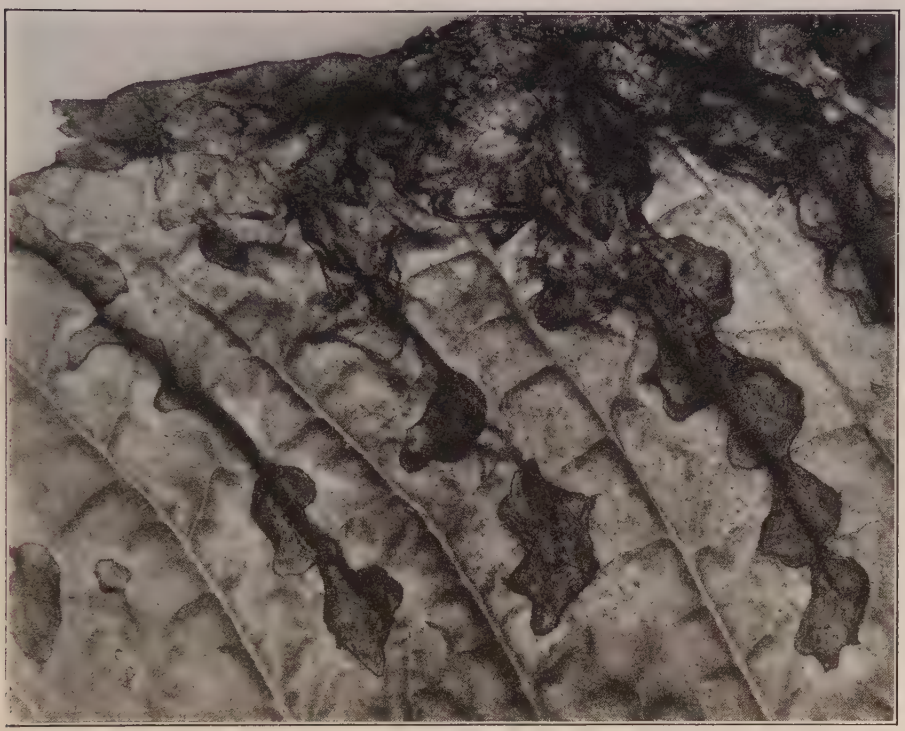

Figure 12.—A portion of a tobacco leaf showing relation of drought-spot to veins and leaf margin. Natural size.

blanched (they may be brown when first formed) and form irregular patterns of rings and zig-zags on the leaf. They are most numerous near the veins and often surround them as shown in figure 13. We will refer to this condition as ring-spot; the grower sometimes calls it ring-worm. The cause of ring-spot is unknown. We have not succeeded in isolating an organism from the spots which proved pathogenic and it seems likely that it is due to some disturbance in the nutrition of the plant. This is suggested by the location of the spots with reference to the veins and also by observations that affected plants are often restricted to certain areas in the field, especially where old buildings have stood or on the site of former gardens. Ring-spot is similar in some respects to the spot which Valleau calls "mosaic speck-spot." The two spots are probably not identical. Ring-spot is not always associated with mosaic.

INFECTION OF FLOWERS

In a field where leafspots of blackfire are prevalent flower infections are often found on the plants that have been allowed to set seed. Infections occur commonly on the calyx, especially on the lobes, and the corolla and seed-pod (capsule) may also be infected. The spots are small, quite black or dark-brown in color, and are usually angular. The calyx lobes are blackened and recurved as shown in figure 14. Wildfire infections also occur on the calyx, corolla and capsule. The

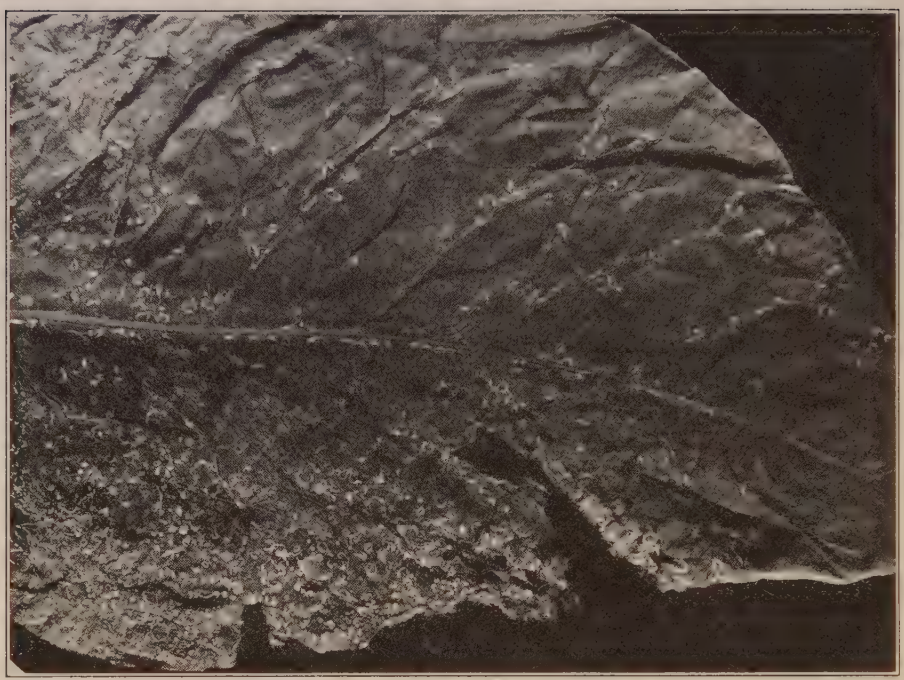

Figure 13.—Ring-spot, a non-parasitic disease of tobacco. Greatly reduced.

Figure 14.—Blackfire spots on tobacco flowers produced by pure culture inoculation. Photographed two weeks after inoculation.

spots are less characteristic than the wildfire spots on the leaf, and are not so easily distinguished from the blackfire spots. They are paler in color, however, and are larger and less definite in outline. The halo is not conspicuous as a rule.

The infection of tobacco flowers is of importance since it results in the contamination of the seed and the transmission of the pathogene in this way. Valleau has suggested that infection of the seed-pods may be avoided by covering the flower stalks with paper bags.

CAUSE OF BLACKFIRE

Blackfire is caused by a schizomycete, **Bact. angulatum,** and wildfire by a distinct but quite similar species, **Bact. tabacum.** The prevailing belief among farmers that these diseases are caused by wet weather or fertilizer has some foundation in fact since their occurrence and severity is greatly modified by rainfall and the nutrition of the host.

Proof of the causation of blackfire by **Bact. angulatum** was first establihsed by Fromme and Murray and was later confirmed by studies of Wolf and Moss (11) in North Carolina and Valleau (12) in Kentucky. The writers have isolated the organism repeatedly from lesions on seedling and mature leaves and have obtained infection on leaves and floral parts from pure culture inoculations in greenhouse and field. We have also confirmed Wolf and Foster's proof of the causation of wildfire by **Bact. tabacum** as have also Chapman and Anderson in their studies in Massachusetts. It has been demonstrated that both organisms produce infection readily through uninjured tissue, the infection court evidently being the stomata or marginal water-pores (hydathodes). Fromme and Murray found that infection with **Bact. angulatum** takes place with equal facility through the upper and lower leaf surfaces and Chapman and Anderson find this to be also true for **Bact. tabacum.** Valleau, however, obtained infection with both organisms most readily through the lower leaf surface, but few infections developing when the inoculations were made on the upper surface.

Rainfall is essential for vigorous development and spread of infection in the field; neither disease is propagated to any appreciable extent during periods of drought. Rainfall provides surface moisture on the leaf which is essential for infection, and the splashing and blowing of rain-drops during rainstorms acts as the chief agency in field dissemination. Abundant rainfall is also conducive to rapid growth of the host and the vigorous succulent plant is especially subject to severe infection.

The incubation period of blackfire is modified by temperature and by the vigor of the host as shown by Fromme and Murray. This is probably also true of wildfire. The spots appear first on the most vigorous plants and high temperatures favor rapid development of infection. Under the most favorable conditions the spots may appear within four or five days; a much longer period is required under unfavorable conditions.

DISSEMINATION AND DEVELOPMENT OF INFECTION

An inquiry into the methods of dissemination of the blackfire pathogene involves the problem of introduction and spread in the plantbed and that of introduction and spread in the field. It has been clearly evident throughout our study that successful control of blackfire in the field is dependent to a very great extent, if not entirely, on the prevention of infection in the plantbed.

Plantbed Studies

Our studies of blackfire infection in the plantbed indicate that although the organism may be introduced in a variety of ways two agencies, the seed and the canvas[1], are chiefly responsible. Other agencies of dissemination such as manure, soil, man, etc., are of distinctly minor importance by comparison.

[1]The thin cloth cover which is used on the plantbed as a protection against cold and insects is commonly called canvas by tobacco growers in Virginia.

Evidence obtained early in our studies indicated the probability of dissemination of blackfire on seed. Seedlings of different varieties grown in the same plantbed showed different degrees of infection, in some cases no infection on some varieties and abundant infection on others. Similar observations were made on seedlings of the same variety but from different seed lots. Evidence of the same nature was also obtained for wildfire. Following our introduction of the practice of seed disinfection, comparisons between seedlings from disinfected and non-disinfected seed showed greater freedom from infection as the result of seed disinfection. Proof that blackfire is a seed-borne disease was also obtained in controlled experimental tests.

A test planting of 90 different lots of disinfected seed, with corresponding checks, was made at Chatham, Virginia, in 1921. The seed samples came from various parts of the State and were taken from seed sent to us by farmers for treatment. The plantbed soil was newly cleared and burned during the winter. New lumber was used for the frame-work of the bed which was separated by board partitions into small compartments each of which was sown with a separate sample. The bed was covered with new canvas. Two materials were employed for seed disinfection, formaldehyde (1-16) and corrosive sublimate (1-1000), and 45 lots were treated with each. When the plants had reached the size for transplanting they were examined for evidence of blackfire and wildfire. No infection was found in any compartment sown with disinfected seed, but 23 of the check lots showed blackfire infection. Of the treated lots which corresponded with the 23 infected checks, 10 had been treated with formaldehyde and 13 with corrosive sublimate, both materials had been fully effective. No wildfire infection developed in any lot.

Additional proof of seed transmission was obtained in tests at Blacksburg in the same year. All other sources of infection except the seed were eliminated in these tests. The effect of contaminating the seed with the organism and of top dressing the plants with chaff from tobacco seed was determined. The seed used was of the Lizard Tail variety and was obtained from disease-free pods. Three plats were provided: one was sown with seed that had been soaked in a suspension of **Bact. angulatum** from pure culture and the others with uncontaminated seed. One of the latter was top dressed with chaff that had been cleaned out of a number of lots of tobacco seed, the material being applied after the plants had made a good growth. The other plat served as a check. Examination for blackfire was made when the plants were large enough for transplanting. Infection was found on 10 per cent of the plants from the contaminated seed and on 10 per cent of those that had been top dressed with chaff. No infection occurred in the check.

Another plantbed test at Blacksburg in 1920 gave evidence of seed transmission of wildfire as well as of blackfire. This test was planned to determine the effect of artificial contamination of disinfected seed with the two organisms and the transmission of infection with chaff from infected seed pods. The treatment of plats and results are shown in table 2. Two varieties were used the Lizard Tail being obtained from infected pods in a field severely damaged by blackfire and the Kentucky Yellow from a field infected with both diseases. Pods of the latter were selected with particular reference to wildfire but it is evident from the results that blackfire predominated. All seed except that used for the checks were first soaked for 15 minutes in 1-125 formaldehyde followed by washing in sterile water. The seed used for plat 2 was then contaminated by placing it in a suspension of **Bact. angulatum** and that used for plat 6 was treated in the same way with **Bact. tabacum.** Plats 3 and 7 were top dressed as soon as seeded with broken-up seed pods of the respective varieties. All beds were seeded on April 13 and the first infections were noted on May 29. A final inspection was made on June 18

TABLE II.—*Dissemination of blackfire and wildfire by seed contamination and chaff from infected seed pods.*

Variety	Plat	Treatment	Number of infected plants	
			Blackfire	Wildfire
	1	seed disinfected	0	0
Lizard Tail	2	contaminated with blackfire culture	11	0
	3	top dressed with chaff	10	0
	4	check	37	0
	5	seed disinfected	20	0
Kentucky Yellow	6	contaminated with wildfire culture	20	9
	7	top dressed with chaff	9	13
	8	check	33	1

every plant being gone over carefully and the number infected with blackfire and wildfire recorded. These are shown in the table. Through an oversight the total number of plants in each plat was not determined so that it is not possible to reduce the figures to percentages for better comparison. The number of plants was approximately equal, however, in all plats except 3 and 7 which had a reduced stand as the result of the addition of chaff. The numbers of infected plants are, therefore, comparable except in these plats. The results in the Lizard Tail variety may be summarized as follows: the disinfectant used was fully effective in preventing dissemination of blackfire on naturally contaminated seed; seedling infection with blackfire was obtained by artificial contamination of seed with the organism from pure culture and by top dressing of soil with chaff from infected pods. No wildfire occurred in this variety as was to be expected since none occurred in the field from which the seed were obtained. The results in Kentucky Yellow are as follows. Wildfire: The efficiency of the disinfectant is uncertain since only one infected plant developed in the check; it is demonstrated that wildfire may be transmitted on naturally contaminated seed, on seed artificially contaminated from pure culture, and on chaff from infected seed pods. The chief point with reference to blackfire in this variety is that the disinfectant was only slightly effective. The number of infected plants was reduced from 33 in the check to 20 in plats 5 and 6. No explanation of the variation between these results and those obtained in the Lizard Tail variety is offered. They indicate, as do subsequent studies, that the low concentration of formaldehyde employed does not insure adequate disinfection with a 15-minute exposure. A much higher concentration was employed in later work.

The poor growth of plants obtained in the plots which were top dressed with chaff from seed pods has been duplicated in other tests where parts of the tobacco plant have been applied to the soil of the plantbed. In our plantbed tests at Chatham we attempted to determine the transmission of blackfire on infected leaves that had been subjected to different curing processes. Infected leaves from the crop of the previous year were crushed and applied as a top dressing in sections of the plantbed as soon as the seed were sown. Leaves of flue-cured, fire-cured (smoke-cured) and sun-cured tobacco, and of uncured tobacco that had stood over winter in the field were used. No plants were obtained except in the sections where fire-

cured and uncured tobacco were applied and these showed a marked reduction in stand. Blackfire infection was found on a considerable number of plants in both of these lots, while the checks were free from infection. The overwintering of the organism on fire-cured tobacco is to be expected since high temperatures are not used in this method of curing; it is also probable that the blackfire organism survives the sun-cure. It seems highly improbable, however, that it survies the flue-cure in which temperatures of 180° to 190° F are attained. This is well above the thermal death point of both the blackfire and wildfire organisms, neither of which withstands an exposure of 10 minutes at 50° C (124° F) (10). Wolf and Foster (9) were unable to isolate the wildfire organism from diseased leaves that had been flue-cured.

The possibility of dissemination of wildfire by the use of canvas was first demonstrated by Wolf and Moss **(11)**. They obtained infection where old canvas was used but none in comparable tests with new canvas. We have seen a number of cases in our field studies of farm plantbeds which indicated the carry-over of both blackfire and wildfire on old canvas. In one case in Campbell County in 1921 a farmer had prepared two plantbeds on new land well removed from tobacco fields. The beds were about 50 feet apart. Both were sown with disinfected seed from the same package. One bed was covered with new cloth, the other with cloth that had been used on a bed of the previous year. The crop of that year was reported to have been severely damaged by blackfire. About 10 per cent of the plants in the bed covered with old canvas were found infected with blackfire when examined just before transplanting. A very careful search for infected plants was made in the bed covered with new canvas but not a single infected plant could be found. Additional cases which indicated clearly the dissemination of both diseases on canvas have been observed in our field studies and it is evident that this is a common method of carry-over of infection from year to year and one of great importance in the control of both diseases.

There are no doubt many additional ways in which the pathogenes may be introduced into the plantbed. Evidence that both may overwinter in soil and manure was obtained. The soil of the plantbed cannot be a factor of great importance in the general problem of control in Virginia since it is the usual practice to prepare a new bed each year on land newly cleared for this purpose. Occasionally, however, the same bed is used a second year and in such cases it is possible that the pathogenes may persist in the soil especially when it has not been burned over. We have seen no direct evidence of this but Wolf and Moss report the overwintering of wildfire in old, unburned plantbed soil, and we have seen cases where both organisms overwintered in the field and spread to the plantbed in the spring. This was true of three cases in 1921, two of blackfire and one of wildfire. The plantbeds in these cases were near the borders of tobacco fields of the previous year and the localization of infection in the sides of beds nearest the fields indicated clearly the spread of the pathogenes from field to bed. In all three instances the fields had not been plowed until late spring. Many plants in these fields had survived the winter and threw out new shoots during the unusually warm weather of the late winter of that year. It seems probable that this was a factor of considerable importance in the carry-over of infection.

If manure which contains refuse from a diseased tobacco crop is used on the soil of the plantbed it is quite probable that seedling infection will result. Very suggestive evidence of this was seen for both diseases. Tobacco stalks are sometimes used for bedding and leaves that are severly diseased may be consigned to the manure pile. The use of manure on the plantbed is not common, however, on account of the introduction of weed seeds.

The rapidity of the spread of infection in the plantbed from the primary infections is modified by conditions. The most important factor in spread appears to be rainfall, i. e. the splashing of contaminated rain drops from plant to plant. Walker (8) has shown that the spread of the cabbage black-leg fungus (**Phoma lingam**) in the seed bed is determined largely by the exposure of the plants to rainfall. In his experiments a portion of a bed sown with infected seed and protected from rainfall showed only 0.5 per cent affected plants as compared with 29 per cent when exposed to rainfall and 39 per cent when watered frequently. It has been our experience that the most rapid spread of infection in the tobacco plantbed occurs after the removal of the canvas which no doubt affords some protection against splash infection. The handling of plants incident to weeding and transplanting is also an important factor in the transfer of infection. We have repeatedly noticed a marked increase in infection within a few days after the first transplants were pulled. Transplanting is done during wet weather and the wet surface of the plants is ideal for dissemination of the pathogenes and infection.

No evidence that insects transmit blackfire has been seen. They are usually abundant in plantbeds, especially flea-beetles. It seems probable that flea-beetles are capable of transmitting wildfire, since spots centering around their punctures are sometimes seen, but Chapman and Anderson have not been able to demonstrate this in a number of tests. Although the evidence at present does not preclude the possibility of transmission of either disease by insects in the plantbed or field, it indicates clearly that neither is dependent on insect transmission for vigorous development.

In summarizing the data on introduction and spread of blackfire, in the plantbed the following points are considered to be established:

1. That the organism is seed-borne as shown by planting tests of naturally and artificially contaminated seed, and by seed disinfection tests.

2. That the pathogene may be carried over from one year to the next on chaff from seed pods or on leaves that have not been cured at temperatures above its thermal death point.

3. That the pathogene may winterover on the plantbed cover.

4. The evidence indicates also that the pathogene may be introduced into the plantbed in manure, and that it may overwinter in the soil under certain conditions.

All of the four above points are considered to be equally true of wildfire.

Field Studies

It has been evident throughout our studies that a close relation exists between the occurrence of disease in the plantbed and the severity of infection in the field and that the transplanting of infected seedlings constitutes the main source of introduction of blackfire and wildfire in the field. Data on this relation were secured during two seasons by a study of plantbeds and fields on 38 farms in Charlotte County. The plantbeds were inspected just before transplanting. The fields were inspected once or more during the growing season and again at harvest when a rough estimate of loss was made. The fields are grouped in two classes as shown in table 3, one group comprising those fields which were set from beds with slight or no seedling infection, and the other those which were set with seedlings showing moderate to severe infection. The estimated percentage of loss for each field is given with the average for the group. The chief disease was blackfire. It was

TABLE 3.—*Relation between seedling infection and field losses.*
(The figures show estimated field loss in percentage.)

Year	Seedling infection	No. of fields	Incidence of disease	Average
1919	slight or none	4	0- 0- 0- 1	0.3
	mod. to severe	12	2-10-15-15-20-20-25-35-35-40-50-50	26.4
1920	slight or none	12	0- 0- 0- 1- 1- 1- 1- 1-15-20-20-35	7.9
	mod. to severe	10	10-10-20-20-20-20-25-25-25-80	25.5

present in 10 of the 12 beds of the moderate to severe group in 1919, and in all of the beds of this group in 1920. Wildfire was present with blackfire in 4 beds in 1919 and 3 in 1920. Two of the beds of 1919 had wildfire infection only. The average field loss by groups shows very strongly in favor of the disease-free or slightly infected seedlings. It is to be noted in 1920 that four of the fields from slightly infected seedlings sustained losses greatly in excess of the others of this group, and it seems probable that there may have been important sources of dissemination of disease other than the seedlings in these cases.

There are no doubt many possible sources for introduction of disease in the field in addition to the seedlings, such as, overwintering in the soil, applications of disease bearing material, dissemination by various agencies from nearby fields, etc. Seedlings which are free from infection in the plantbed may be contaminated during transplanting, and a particularly favorable opportunity for this is furnished when neighbors help each other, as pointed out previously. Exchange of plants between farmers may introduce infection into an otherwise clean field. A good example of this was seen in one instance where the replants which had been obtained from a neighbor's bed were infected with blackfire while the original setting was free from infection.

We have no experimental evidence as to the longevity of the blackfire and wildfire pathogenes in the soil. Observations which were cited in the discussion of plantbed infection indicate, however, that both may overwinter in the soil under certain conditions. There has been no evidence in our field studies that overwintering in the soil played an important part in the development of disease in the crop as a general rule, or even in specific instances. It has been the common experience of farmers that infection occurs as severely in a newly-cleared field, or one in a rotation, as in land that has been cropped with tobacco the previous year. One would not expect any difference of moment, however, if infected seedlings were used. It seems that the greatest probability of carry-over in the soil would exist when plowing is delayed until spring and especially so during mild winters. The unplowed stubble survived the mild winter of 1920 in many cases and put out new growth in the spring. The overwintering of the pathogenes on the plants under these conditions seems probable. It is the opinion of the writers that fall plowing greatly reduces the possibility of such carry-over.

It has been shown in the plantbed studies that applications of manure which contains refuse from a diseased crop may cause seedling infection and this is true unquestionably also in the field. It seems equally true that applications of tobacco stalks, damaged leaves or other material from the crop of the previous year may very probably serve to introduce the pathogenes unless the material has been flue-cured. It is unlikely, however, since both organisms are non-spore-formers, that

PLATE I.—Blackfire spots on a leat of bright tobacco. The spots are typically angular on this type of leaf.

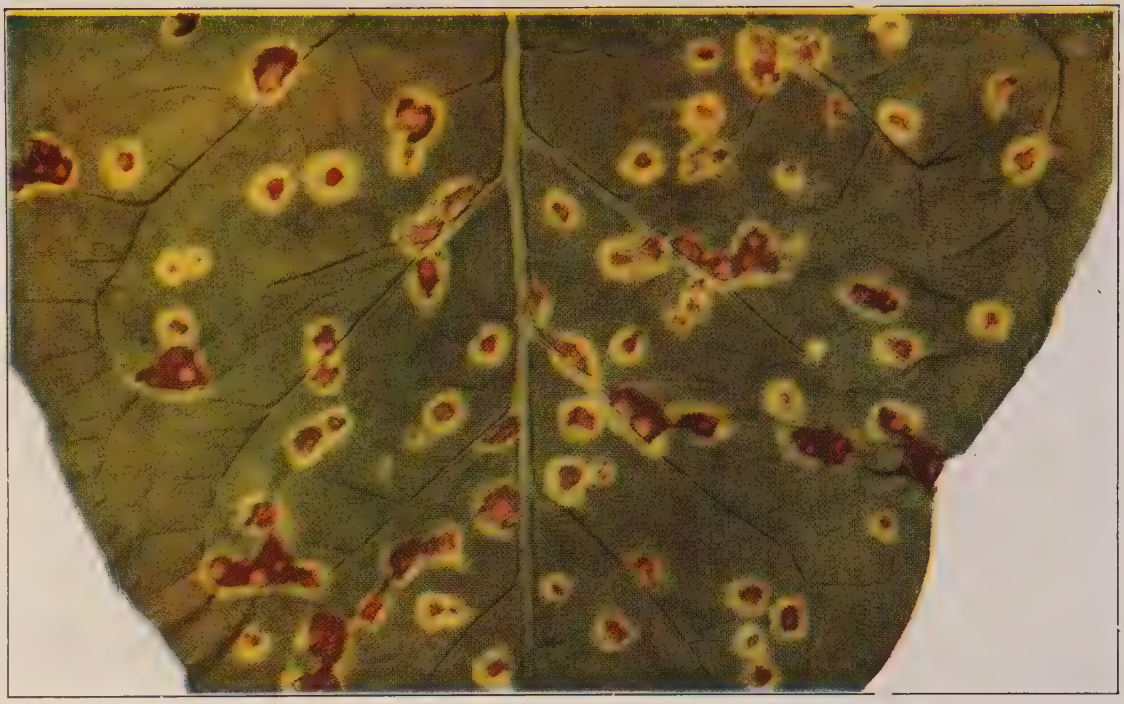

PLATE II—Wildfire spots in medium-early stage of development.
The halo is conspicuous at this stage.

they retain their viability on dead material longer than a year. The question of dissemination in fertilizers and the relation of fertilizers to severity of disease will be discussed in a later section.

When fields are in close proximity spread of infection may take place between them by natural agencies. Dissemination may also be accomplished by workers in cultivation, worming, topping, suckering, etc. The constant working and handling necessary in tobacco culture is an important factor in spreading infection, especially so if done when the plants are wet with dew or rain. Spread of infection from field to field by natural agencies, such as wind-blown rain, appears to be quite limited; a space of a hundred yards or so between fields seems to afford protection from spread by natural agencies. The writers maintained two plats of tobacco in one season which were separated by a strip of corn 150 feet in width. One plat was inoculated with wildfire and was infected throughout the season, while the other plat remained free from infection. In another instance two fields on opposite sides of a road were observed. One showed wildfire infection throughout the season, the other showed no infection. The fields were owned and worked by different men and this no doubt explains the lack of transfer of infection. After the disease is established in the field abundant opportunity for spread is provided by the rainfall of a normal season and by the working of the crop.

The Relation of Rainfall to Infection

Dissemination in the field is dependent to a very marked degree on seasonal conditions, of which rainfall is most important. The most rapid spread of infection follows heavy rains. The relation between rainfall and epidemics of blackfire and wildfire is so striking that the grower is apt to consider the rain to be the cause of these diseases. As stated previously infection takes place rarely, if at all, when the leaf surface is dry. When the leaf is wet with rain or dew the bacteria in the dry tissues of the spot float out into the drops of water on the surface. Other rain drops striking the leaf splash the contaminated drops to other plants and provide surface moisture for the entrance of the pathogenes into the sound tissues. Wind accompanied by rain serves to spread infection to greater distances. The action of wind is shown by the greater intensity of infection on leaves on the windward side of the plants which is commonly noticeable following severe storms. Chapman and Anderson have followed the spread of wildfire from a single diseased plant or row and have found the area of new infection to be invariably greater to leeward than to windward. They find, however, that wind unaccompanied by rain is of slight importance in dissemination.

An experimental planting to test the rate of spread of wildfire was made at Blacksburg in 1920. The plants which were of the Kentucky Yellow variety were grown in the greenhouse and were transplanted to the field on June 12. They were set 3 feet each way to form a solid rectangle, 19 rows wide with 14 plants to the row, a total of 266 plants. The plants on the border were atomized with a suspension of **Bact. tabacum** shortly after transplantation. An inspection of the planting was made at intervals of about 7 days to determine the rate of spread of infection from the inoculated border plants. The first record was made July 22. At this time many of the border plants and a few plants in the second series, showed infection; a total of 33 plants in all or 12 per cent. One week later, July 29, infection was found on 80 plants, or 30 per cent of the total. The spread had been greater from the west and north, the direction of prevailing winds. Infection had progressed inward as far as the 6th series from the west, the 5th from the north,

the 2nd from the east and the 3rd from the south. On August 7, 115 plants (43 per cent) showed infection. The greater rapidity of spread from west to east than vice versa is shown by the fact that there were 75 infected plants in the west half of the area and 40 in the east half. On August 13, 179 plants (67 per cent) showed infection, and spread was practically complete by August 28 when 263 of the 266 plants (99 per cent) were found to be infected.

It will be seen from the foregoing that, although a steady increase in infection took place the spread was not as rapid as might be expected. The season was quite wet and seemed to be very favorable from that standpoint. It is apparent that increase in infection is often more rapid than this in the tobacco section and no doubt temperature is an important factor, the higher summer temperatures of the tobacco section no doubt being more favorable for rapid development than the lower summer temperatures at Blacksburg.

Although infection may take place at any time during the growing season when climatic conditions are favorable, the most rapid spread is during the period of most rapid growth of the host. As the plants increase in height and spread the opportunity for propagation of the pathogenes and transfer from plant to plant is increased, and when the topping stage is reached the maximum conditions for spread have been realized. The early stages of an epidemic are commonly overlooked by the tobacco grower who usually states that the disease appeared suddenly and spread over the field in a few days. Severe damage generally occurs during the month of August but a few cases where the epidemic was well under way in July have been recorded. Our records show the following dates to have been the approximate time of general appearance of blackfire in epidemic form during the period of our study of the disease: 1917, August 1; 1918, August 9; 1919, August 6; 1920, July 12. This indicates that the months of July and August are the most critical ones from the standpoint of development of disease and that the precipitation during this period determines to a large degree the severity of injury. A comparison between the rainfall of the months of July and August of 1920 and 1921 is shown in table 4. The season of 1920 was marked by excessive rainfall during the critical months with a very severe epidemic of blackfire and wildfire while that of 1921, in sharp contrast, was one of deficient rainfall with only a slight development of disease. Our studies of plantbeds show the diseases to have been equally prevalent on seed-

TABLE 4.—*Rainfall for months of July and August,* 1920 *and* 1921 *at three stations in the tobacco section.*

Station	Total inches of rainfall		Departure from normal	
	1920	1921	1920	1921
Clarksville	11.68	2.93	+2.38	—6.37
Danville	12.49	2.27	+3.85	—6.37
Lynchburg	11.58	4.39	+3.30	—3.89

lings during both seasons; the dry summer of 1921, however, effectively checked development of disease in the field, while the excessive rainfall of 1920 provided ideal conditions for vigorous development. The writers observed one case in 1920 where practically all of the seedlings used in one field were affected with wildfire. There was some increase in infection during the early part of the season but after dry weather set in there was practically no additional spread and at harvest only an occasional recent infection could be found. The damage to the crop as a whole was slight. Similar observations were made with reference to blackfire.

The common belief that fertilizers cause blackfire and wildfire has its foundation in the fact that the susceptibility of the host is greatly modified by its nutrition. There has been no evidence in our work to suggest that the pathogenes are carried in commercial fertilizers. It has been pointed out, however, that it is possible for them to retain their viability from one season to the next on tobacco material that has not been cured at high temperatures, and it is possible that the incorporation of such material in a fertilizer may lead to infection, unless it has been subjected to some other sterilizing process. According to our information the tobacco material which is commonly used in commercial fertilizers consists of stems from which the nicotine has been extracted. The steaming process used in the extraction of nicotine should destroy any bacteria which still remain viabile at this time, and there should be no danger in the use of fertilizers which contain such extracted material.

The nutrition of the host and its susceptibility to infection is greatly modified by soil fertility. The tobacco plant responds in a very marked way to fertilizer applications. Fromme and Murray state that the greatest injury from blackfire is found on the most vigorous plants. In a study of fertilizer plats they found the greatest vigor of growth, accompanied by the greatest blackfire injury, on plats which had received applications of phosphorous. Our studies are in agreement with these observations. An epidemic of blackfire at the substation in Charlotte County in 1919 provided an opportunity for further study of the effects of fertilizer applications on this disease. The plats in question received varying quantities of three materials, acid phosphate, nitrate of soda and sulphate of potash. The percentage of plants affected with blackfire was determined for each plat on July 24, as shown in table 5, shortly after the plants in the most forward plats had been topped. The growth of plants was recorded as very poor, poor, fair, or good. The percentage of infection corresponded closely with the growth of plants, as shown in the table, with a marked difference between the plats with poor plants and those with good plants, the latter showing the highest percentages of infection. Good growth was obtained only on those plats which received phosphorous, either alone or in combination with other materials. Nitrogen in the amounts used had little effect on the disease, there being no appreciable difference, when the other mater-

Table 5.—*The effect of fertilizers on blackfire infection. The data are from 200 plants per plat.*

Plat No.	Pounds per acre of material			Percentage infected plants	Growth of plants
	Acid phosphate	Nitrate of soda	Sulfate of potash		
4	...	...	...	12	very poor
16	...	...	...	21	poor
3	...	...	200	21	do.
1	...	600	...	22	do.
5	...	600	200	64	fair
9	350	300	100	93	good
11	350	600	200	75	do.
2	700	...	...	86	do.
6	700	...	200	98	do.
13	700	300	100	85	do.
10	700	300	200	92	do.
7	700	600	...	87	do.
12	700	600	100	77	do.
8	700	600	200	91	do.

ials were constant, between 300 and 600 pounds of nitrate of soda (compare plats 12 and 13, and plats 8 and 10). Increase in potash appeared to increase susceptibility to some extent (compare plats 8 and 12, and plats 10 and 13). When examined two weeks later all plats showed practically 100 per cent of infected plants, the degree of infection was, however, comparable to the percentages of infection shown on the previous inspection. It has not been determined whether the difference in degree of infection is due to failure of infection or to failure of the pathogene to develop vigorously following infection. It is probable that differences in both respects occur. Fromme and Murray in greenhouse inoculation tests found that the spots which develop on old leaves are very small in comparison with those on young leaves, the former being mere pin pricks in size and often invisible except in transmitted light. It is probable that infections of this nature occur on slow-growing, poorly nourished plants in the field.

Additional evidence that the pathogenecity of the blackfire organism is closely related to the metabolism of the host was obtained in a study of the effects of topping on development of infection. The work was done at the Charlotte station in 1919. Each plat consisted of 90 plants of the Lizard Tail variety. All plants were topped on July 8, the height of topping varying with different plats from 8 to 14 leaves, as shown in table 6.

TABLE 6.—*The effect of height of topping on development of blackfire.*

Height topped	Degree of infection	Yield pounds	Percentage by grades		
			Longs	Shorts	Lugs
8 leaves	very severe	31	..	..	100
9 leaves	do.	35	11	6	83
10 leaves	severe	40	15	21	64
11 leaves	do.	37	14	24	62
12 leaves	moderate	34	..	9	91
13 leaves	do.	34	..	18	82
14 leaves	do.	43	..	21	79

The difference in severity of infection at the different heights of topping was very marked, infection being most severe on the plants topped at 8 leaves and least severe on those topped at 14 leaves. Severity of infection corresponded with the growth of plants. The plants topped at 8 and 9 leaves showed a very rank, vigorous growth with very large thick leaves, and very severe infection. Those topped at 10 and 11 leaves, the usual height for dark tobacco, were intermediate in vigor of growth and severity of infection, and those topped at 12 leaves or above produced small leaves which were lacking in body. The yield data, shown in the table, was obtained from the cured tobacco which was graded by Mr. M. O. Wilson, superintendent of the substation. The variations in total yield between plats are of slight significance, but the percentage by grades shows strongly in favor of the plats topped at 10 and 11 leaves. Loss in grade below this point was caused by severe blackfire injury and that above by lack of leaf size and body.

An interesting sidelight on the effect of nutrition on the development of blackfire was obtained during the field survey work. One farmer stated that he makes a practice of growing his seed plants on unfertilized land on account of the freedom from infection thus obtained.

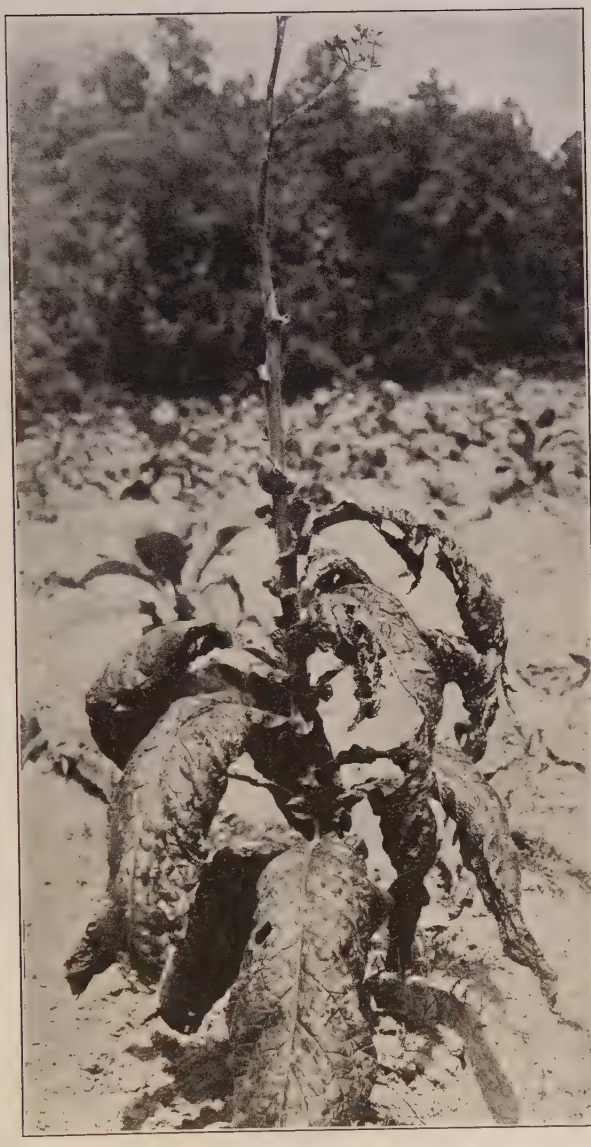

Figure 15.—A seed plant of tobacco severely damaged by wildfire. The remainder of the crop was harvested green to avoid further damage. Photographed August 9, 1919.

The severity of wildfire is also modified by the growth of the host. Wolf and Moss state that plants which make the rankest growth are most severely affected. To quote:

"Observations show that plants which have made a rank growth, induced by the too liberal application of fertilizer, particularly nitrogenous materials, or by proximity to ditches or to situations which are normally well supplied with organic matter and water, apparently become more severely affected than plants which have made a normal growth."

Chapman and Anderson have noted that wildfire is most severe in sections of plantbeds where excessive applications of nitrogen have been made, and also that applications of potash tend to check the spread of infection in the plantbed.

Some data on the effect of fertilizers on wildfire were obtained at the substation at Appommattox in 1911 in a series of plats which were planned to test the effect of different sources of nitrogen and potash on the yield of dark tobacco. The plats were inspected on August 11, and a very marked difference in the severity of infection between them was noted as shown in table 7. The check plat showed very

TABLE 7.—*Effect of fertilizer applications on severity of wildfire at Appomattox, Va.*

Plat No.	Kind and quantity (pounds) of material applied			Severity of disease
	Acid phosphate	Nitrogenous material	Potash source	
4				very slight
1	800			do.
2	800	dried blood, 600		slight
5	800	nitrate of soda, 567		do.
6	800	dried blood, 625	sulphate of potash, 100	severe
7	800	do.	muriate of potash, 100	very severe
3	800	nitrate of soda, 136 tankage, 454 dried blood, 189	(tankage)	very severe

slight infection, as did also the plat which received phosphorous only. The most severe infection occurred on plats 6, 7 and 3 which received potash in addition to nitrogen and phosphorous. Lack of potash appeared to check infection to a marked degree.

The effect of topping on wildfire has not been noted, but untopped plants for seed production have been seen which were very severely infected, practically every leaf being destroyed. Such a plant is shown in figure 15.

Additional data from experimental plats are needed for a thorough understanding of the relations of different fertilizers to the development of blackfire and wildfire. It seems evident that both diseases develop better on plants with well balanced nutrition than on those with unbalanced nutrition. This is contrary to the general belief among farmers who commonly consider severe infection to be due to a deficiency in the fertilizer, especially to lack of potash.

SUSCEPTIBILITY OF VARIETIES

Such differences as exist in susceptibility to blackfire and wildfire between the varieties of tobacco grown in Virginia appear to be of slight importance, and seem to offer little promise of effective control through choice of varieties. It is true also that the individual plants of a variety appear to differ but slightly, if it all, in susceptibility. A test of susceptibility to blackfire conducted with eight va-

rieties in 1919 showed noticeable differences in severity of infection, but no variety showed any marked degree of resistance. The varieties were classed according to severity of infection in the following order, grading from most to least severe infection: Eureka, Sweet Orinoco, Little Orinoco, Lizard Tail, One Sucker, Big Orinoco, Blue Pryor, Kentucky Pryor. We have observed blackfire on 19 additional varieties with indications that none possessed any marked degree of resistance. Wildfire infection has been observed on 13 varieties. The evidence with respect to wildfire indicated that probably all varieties are susceptible enough to be severely damaged under conditions favorable for infection. The varieties on which blackfire and wildfire have been seen are listed below, those infected with wildfire as well as blackfire being indicated by an asterisk.

*Adcock	*Hester	Pryor, Blue
Adcock, Little	*Irvin Green	Pryor, Kentucky
Burley, Lockwood	*Kentucky Yellow	*Pryor, Yellow
*Cash	*Lizard Tail	Pryor, Silky
Cutcher, Improved	One Sucker	Ray
Eureka	*Orinoco Little	*Stand-Up Kelly
*Flannagan	Orinoco, Big	*Warne
Granville Bright	Orinoco, Sweet	Warne, Narrow-Leaf
*Goldleaf	Orinoco, White-Stem	*White Willow-Leaf

CONTROL

Our experimental work on the control of blackfire has been conducted along the lines of seed disinfection and plantbed sanitation, and has been supplemented by studies of the efficiency of these measures as applied to farm plantbeds. It has been apparent that the first step in control must involve the production and use of disease-free seedlings. There has seemed to be little possibility of effective economical control in the field after the disease has become established there.

Methods and Materials Used in Seed Disinfection

Two disinfectants have been employed in our work, formaldehyde and corrosive sublimate. The effect of concentration and period of exposure will be discussed in a later section.

The following methods were used in disinfection of seed with formaldehyde. The seed are poured into a glass-top mason jar and are covered with about twice their volume of the disinfectant. The cover is applied and the jar is shaken vigorously from time to time during the exposure period. The contents of the jar are then strained through a kitchen strainer which is covered with a square of cheesecloth to retain the seed. The seed are then washed thoroughly in running water and spread out on the cloth to dry. Various methods of drying have been used. Small quantities of seed dry in a few hours when spread on blotters at room temperature. A wire frame spread over a radiator has also been used with excellent results. Exposure to moderate heat in drying has no effect on the gemination of the seed. In field work, where good facilities for drying were not available, rapid drying has been secured with a small hand centrifuge which was fitted with metal cups with perforated bottoms. The centrifuge and other equipment used in the field work is shown in figure 18. When placed in the centrifuge the greater part of the water is thrown off the seed in a minute or two and they complete drying in a short time on removal.

Treatment of seed with corrosive sublimate has also been practiced in mason jars, but a simpler method which appears to be equally effective has been more often used. The seed are placed on cheese cloth squares which are tied to form a bag. A number of these bags are then placed at the same time in the disinfectant and stirred with a stick during the period of immersion. They are then washed in running water for a few minutes and dried. In practice as many as one hundred lots have been treated at one time by this method.

The Effect of Formaldehyde on the Pathogenes and on the Seed

In our preliminary tests a 1-125 (1 part of 40 per cent formaldehyde in 125 parts of water) solution was employed. This caused no seed injury for the 15 and 20 minute exposures used but did not produce complete disinfection. It was considered desirable that the period of exposure be as short as possible and tests of higher concentrations were made. These showed that seed could be soaked for 30 minutes in a 2 per cent solution without injury to germination, provided they were washed thoroughly after treatment. The effect of concentration of formaldehyde ranging from 1 to 4 per cent at three periods of exposure is shown in table 8. There were approximately 500 seed in each lot. After treatment they were washed thoroughly in water, dried and placed in the germinator at once. The germinator em-

Table 8.—*Germination of tobacco seed as affected by concentration of formaldehyde and period of exposure. Seed treated October 22, 1920; germination recorded after 18 days.*

Concentration of solution	Period of exposure (minutes)		
	15	30	45
1 per cent	100	100	100
2 per cent	100	100	25
3 per cent	100	80	3
4 per cent	90	3	1

ployed throughout our work, unless stated otherwise, consisted of a petri dish with a layer of wet sand covered with a sheet of filter paper (figure 16). A separate dish was used for each lot of seed. The dishes were incubated in a warm place near the window as light is essential for the best germination of tobacco seed. Two additional exposures of the 4 per cent solution were made which are not shown in the table. The 5-minute exposure gave 100 per cent germination and the 25-minute exposure 15 per cent germination.

The possibility of a residual effect of formaldehyde disinfection was determined on one lot of seed which were stored after treatment for 74 days before testing for germination. The concentration employed was 1-16 (approximately 2 per cent) and four periods of exposure, 15, 25, 30 and 35 minutes, were used. The 35-minute exposure germinated 90 per cent, while the other lots and the checks germinated 95 per cent. Another test made with duplicate samples of the lots shown in table 8 which were held for 84 days before germination showed no residual effect. It is evident that tobacco seed may be stored without injury to germination after disinfection with formaldehyde provided they have been thoroughly washed and dried.

Retarded germination following formaldehyde disinfection has occurred in a number of seed lots in our tests, while many others have shown no evidence of this. The delay has been short in most cases but in a few lots it has extended over a considerable number of days. Records kept on two lots of seed which showed retarded germination showed in one case complete germination of the check in 7 days and the treated in 13 days, and in the other 8 days for the check and 11 days for the treated. In some cases seed which show retarded germination eventually show as high a percentage of germination as the control while in others retarded

Figure 16.—The type of germinator used in testing tobacco seed. The seed in this lot were disinfected by soaking in 1-16 formaldehyde for 15 minutes.

germination is accompanied by seed injury. The relation between retarded germination and seed injury was determined in the same set of samples on which the effect of concentration and period of exposure was recorded in table 8. The germination of the different lots was noted after 10 days and again after 18 days. The data are shown in table 9. There was no delay in germination with 1 per cent formaldehyde for 45 minutes, 2 per cent for 15 minutes and 3 per cent for 15 minutes. The 2 per cent solution caused a slight delay at 30 minutes and a marked delay with severe seed injury at 45 minutes. It is interesting to note that the germination of coffee seed is also retarded by formaldehyde. According to Dowson (4), the germination of coffee seed is retarded from one to three months, according to the age of the seed, after soaking over night in a 0.3 per cent solution.

It is probably true that retarded germination and injury is more apt to occur in seed of low vitality than in seed of strong vitality, and that the difference ob-

TABLE 9.—*Retarded germination as determined by concentration of disinfectant and period of exposure.*

Percentage of formaldehyde	Exposure (minutes)	Percentage of germination	
		10 days	18 days
1	15	100	100
	30	100	100
	45	100	100
2	15	100	100
	30	95	100
	45	1	25
3	15	100	100
	30	2	80
	45	1	3
4	15	50	90
	30	1	3
	45	0	1

tained with different seed lots is due to differences in age and vitality of the seed. No injury has resulted in a majority of treatments with 1-16 formaldehyde and in fact the treatment has improved germination in a number of cases. A test planting of 125 different lots of seed both before and after treatment was made in the greenhouse in 1921. A summary of this test is shown in table 10. The percentage

TABLE 10.—*Germination of tobacco seed treated with* 1-16 *formaldehyde and of corresponding checks, in soil in the greenhouse.*

Percentage of Germination	5	15	25	35	45	55	65	75	85	95	Total No.
Treated seed	3	3	10	6	6	8	10	32	27	20	125
Untreated seed	11	10	5	8	15	9	8	25	19	15	125

of germination was estimated by comparing the stand of seedlings in the different lots which were seeded at a uniform rate. Each of the 10 classes covers a range of ten per cent. For example the 5 per cent column includes all cases showing germination estimated at from 1 to 9 per cent. It will be noted that 89 lots of treated seed germinated 60 per cent or better as compared with 67 lots of untreated seed, 71 per cent against 54 per cent. A further analysis of the test showed that in 47 per cent of the lots germination was equally good in the treated and corresponding untreated lots. In 38 per cent the treated seed germinated best, and in 15 per cent the untreated seed germinated best. A difference of less than 10 per cent was disregarded in these results. An analysis of the 47 lots where the treated seed was superior showed that in 68 per cent the margin between treated and untreated was considerable, the percentage of germination being twice as high or more in the treated lot. Only 6 of the 19 lots, where the untreated seed was superior, showed marked injury to germination. These results are summarized in table 11.

Results which agree closely with these have been reported by French (5) who tested germination of 322 seed lots treated by him in 1921 with 1-16 formaldehyde following our published directions (6). He summarized his results as follows:—"Summarizing the 322 treated and tested samples, only 21 or 6½ per cent were affected by the treatment, and only 9 or 2 4/5 per cent, that is, about 3 in each hundred, were damaged so that a fair stand of seedlings in the plant bed could not

TABLE 11.—*Summary of germination of treated and untreated lots of tobacco seed.*

	Number	Per cent
Germination of treated seed equal or superior to check	106	85
Germination of treated seed inferior to check	19	15
Total	125	100
Marked injury to germination from treatment	6	5
Slight injury to germination from treatment	13	10

be expected.'' He also notes that retarded germination occurred with some seed lots while in others the treated seed germinated as quickly as the untreated, and that retarded germination is often accompanied by seed injury.

The effect of formaldehyde on the blackfire and wildfire organisms has been studied with both naturally and artificially contaminated seed. Seed from pods infected with blackfire and wildfire were given the standard treatment of 1-16 formaldehyde for 15 minutes, washed in sterile water and plated on beef-peptone agar.

Figure 17.—Sterile tobacco plants growing on agar after disinfection with formaldehyde. Photographed three weeks after plating.

Such seed grew normally and produced sterile seedlings (figure 17), the agar medium remaining clean except for occasional fungous or bacterial colonies on some plates which were clearly the result of contamination in handling. A further test was made with artificially contaminated seed. Seed from non-infected pods was placed in an aqueous suspension of **Bact. angulatum** well shaken and allowed to dry. Small lots were then exposed to 1-16 formaldehyde for varying periods ranging from 2 to 25 minutes after which they were washed in sterile water, dried and plated on

beef-peptone agar. The number of seed used to each plate was about 100. A small sampler which was used to obtain uniform numbers of seed gave excellent results. The number of colonies appearing on the plates was recorded after 5 and 10 days, the latter being after the seed had begun to germinate. The colonies on the check plates, seed contaminated but not disinfected, were too numerous to count, and these are not included in the table. Table 12 shows the number of colonies on duplicate plates for each exposure at the 5 and 10 day periods. A rapid decrease in the number of colonies is seen with increase in period of exposure, the most rapid decrease

TABLE 12.—*The relation between period of exposure to* 1-16 *formaldehyde and disinfection of tobacco seed artificially contaminated with Bacterium angulatum.*

Period of exposure, minutes		2	5	7	10	15	20	25
Number of colonies after five days	plate 1	1900	192	3	1	1	0	0
	plate 2	1200	348	10	1	0	0	0
Number of colonies after 10 days	plate 1	numerous		10	15	5	1	0
	plate 2	do.		26	11	2	1	0

taking place between 5 and 7 minutes. Both plates of the 20-minute exposure were sterile after five days incubation, but each developed a single colony by the tenth day after germination of the seed had started. Complete sterility was obtained with the 25-minute exposure together with normal germination of the seed.

A duplicate of this test was also made with the wildfire pathogene. These results are shown in table 13. Complete sterility was not obtained in duplicate with any exposure in this series, a single colony developing on one of the 25-minute plates

TABLE 13.—*Relation between period of exposure to* 1-16 *formaldehyde and disinfection of tobacco seed artificially contaminated with Bact. tabacum.*

Period of exposure, minutes		2	5	7	10	15	20	25
Number of colonies after five days	plate 1	152	5	1	1	0	1	0
	plate 2	72	4	0	0	2	0	0
Number of colonies after 10 days	plate 1	numerous	18	6	4	2	1	1
	plate 2	do.	14	6	2	2	1	0

after 10 days. A study of the location of the colonies on the plates showed that all but one of the thirteen colonies which appeared on the 10, 15, 20 and 25-minute exposures were closely associated with the seed. Nine of these colonies were not seen until after the seed coat had been ruptured in germination. It seems possible that the bacteria may have penetrated the seed coats while they were soaking in the suspension, and that they were consequently less readily reached by the disinfectant.

It seems from the tests recorded above that greater assurance of complete disinfection of tobacco seed would be obtained from a 20 or 25-minute exposure to formaldehyde than from the 15-minute soak which has been used in practice. It seems inadvisable, however, to increase the period of exposure except with seed of known strong viability on account of the possibility of seed injury. It should be recognized further that the conditions of these tests are artificial and their relation to the problem of naturally contaminated seed is open to some doubt. In our con-

trolled plantbed tests, cited previously, complete disinfection against blackfire was obtained with 10 different seed lots, as shown by comparison with the checks, using 1-16 formaldehyde for 15 minutes. Final data with respect to wildfire are lacking as yet.

Figue 18.—Strainer, jar and centrifuge used in formaldehyde disinfection of tobacco seed.

The Effect of Corrosive Sublimate on Tobacco Seed

The possibility of seed injury attendant on the use of formaldehyde in disinfection of tobacco seed, even though it is slight, made it desirable that a less toxic material equally good as a disinfectant be found. Corrosive sublimate appears to serve the purpose admirably; it causes no seed injury and no delay in germination. We have used the strength commonly used in disinfection, 1-1000 (1 part $HgCl_2$ in 1000 parts of water) throughout our work. In preliminary tests with intervals of exposure ranging from 2 to 20 minutes, followed by a brief wash in water, all lots including the check germinated 95 per cent. In later tests it was found that a 30-minute exposure could be used with safety. In practice we have used a 10-minute soak. A considerable number of seed lots that have been tested in the laboratory and also in the soil of the greenhouse have shown no injury from this treatment. The treated seed have always germinated as rapidly and as well as the untreated Treated seed dried and stored for 60 days showed no decrease in percentage of germination. The treatment has given complete disinfection of seed naturally contaminated with both pathogenes, as shown by plating on nutrient agar. In plantbed tests (table 1) complete disinfection was obtained with 13 lots of seed which developed blackfire when sown without treatment. No adequate field check on the laboratory tests with respect to the wildfire pathogene have been obtained as yet, but studies of farm plantbeds indicate that it is probably equally effective for the two organisms. These data are discussed in the following section.

The Efficiency of Control Measures as Applied to Farm Plantbeds

These studies have covered two seasons, 1920 and 1921. Comparisons were made between farm plantbeds in which seed disinfection and sanitation measures were practiced and others in which no treatment was applied. The studies of 1920 were made in Charlotte County and included 31 beds while those of 1921 included 96 beds in a number of counties. It is not to be expected that results comparable to

those of controlled experiments would be obtained with farm plantbeds since opportunity for reintroduction of the pathogenes, which would tend to negative the value of the control measures, no doubt existed in some cases.

The material used for seed disinfection in 1920 was 1-125 formaldehyde. All treatments were made by the writers, each farmer supplying his own seed. The great majority of the tobacco fields in this county had been severely affected with blackfire during the previous year and wildfire was also present but in a much smaller number of fields. Especial effort was made to encourage men who had sustained severe losses to test the value of seed disinfection and all who used treated seed were advised to use new canvas. Inspection of the plantbeds was made just prior to transplanting; 10 beds sown with treated seed and 21 with untreated seed were inspected. Only four of the first group were covered with new canvas as were also nine of the last group. The degree of infection found in the beds was expressed by the terms none, trace, moderate, and severe. Under trace were included all cases where only a very few infected plants were found, much less than one per cent. In no case included in this group did the number of infected plants found in the bed exceed 12, and as a rule there were not more than three or four. All in excess of trace were classed as moderate or severe. In a few of the severe cases practically every plant in the bed was infected. For convenience in tabulation the moderate and severe cases are combined as shown in table 14 which shows the occurence of blackfire and wildfire in the beds, according to the treatment received.

TABLE 14.—*Occurrence of blackfire and wildfire in plantbeds in* 1920

Kind of seed	Kind of canvas	Occurence of blackfire			Occurrence of wildfire		Total No. beds
		None	Trace	Mod.-sev.	Mod.-sev.	Trace	
Untreated	old	2	4	6	..	1	12
do.	new	4	1	4	..	..	9
Treated	old	1	2	3	1	..	6
do.	new	..	4	..	1	..	4

No very definite conclusions can be drawn from the small number of cases included in this study. It is worth noting, however, that the beds in the group with treated seed and new canvas were less affected with blackfire than those of the other three groups; no infection in excess of trace occurred in this group. It is believed that the infection in these cases was due to incomplete disinfection of the seed; a much stronger solution of formaldehyde was used in the work of the following year. A point of especial interest was found in the group of beds with untreated seed and new canvas. Of the four beds which showed no infection three were sown with old seed; three years old in one and five years old in two. Another bed sown with the same three years old seed but covered with old canvas was severely infected with blackfire. It is not known that the freedom from infection shown by the old seed was due to failure of the pathogenes to survive the storage period, rather than to original freedom from contamination. It seems unlikely that non-spore-forming bacteria such as these would survive on the dry seed for longer periods than a year or two and the use of old seed in control is suggested, as a substitute measure for seed disinfection.

Wildfire occurred in only three beds and no conclusions, except that the disinfectant was not completely effective, are justified.

A campaign for the treatment of tobacco seed which was conducted through the extension service provided an excellent opportunity for the study of additional plantbeds in 1921. Approximately 2500 seed lots were treated by representatives of the department of plant pathology during the campaign. Many of the lots were shared by two or more men and a one-half bushel lot was distributed to several hundred farmers. It is estimated that fully 5000 Virginia farmers used treated seed in this year. The use of new canvas or old canvas that had been thoroughly boiled was advised and it was recommended that the plantbed be located on new land well removed from tobacco fields. Two materials were used for seed disinfection, 1-16 formaldehyde and 1-1000 corrosive sublimate. About 900 lots were treated with the former and about 1600 with the latter material.

A thorough inspection was made of 70 plantbeds sown with disinfected seed, the number representing each disinfectant being about equal, and of 26 beds sown with untreated seed. It was found that the majority of the farmers who used disinfected seed had carried out the sanitary measures recommended, only 26 of the 70 visited failed to do so. In order to facilitate comparisons between the beds receiving different treatment they are grouped in three classes as follows:

Class A. Treated seed used and all sanitary measures practiced.
Class B. Treated seed used but sanitary measures omitted.
Class C. Untreated seed used.

The sanitary measures referred to above consisted of the use of sterilized or new canvas and the proper location of the bed. The omission of either consigned the bed to class B. For example, in two cases the canvas was boiled but the beds were located on the border of tobacco fields with clear evidence that blackfire had spread from the fields to the beds. New canvas was used in only a few of the beds in class A, the remainder being covered with old cloth that had been boiled. The occurrence of infected seedlings was recorded by the same symbols as those used in 1920 which are to be interpreted in the same way. In summarizing the data for blackfire, which are shown in table 15, the moderate and severe cases are combined for convenience. Wildfire, as in the previous year, was found in comparatively few beds; the occurrence of this disease is discussed separately following the presentation of the data on blackfire.

TABLE 15.—*Occurrence of blackfire in farm plantbeds in* 1921.

Class	Total No. beds	Number of beds			Percentage of beds		
		None	Trace	Mod.-sev.	None	Trace	Mod.-sev.
A	54	30	11	13	56	20	24
B	16	0	4	12	0	25	75
C	26	2	2	22	8	8	84

A study of the data for this season shows clearly that seed disinfection is of practical value in the control of seedling infection by blackfire when accompanied by the sanitary measures in question. No infection occurred in 56 per cent of the beds so treated and an additional 20 per cent showed infection which did not exceed a trace. Only 24 per cent of the beds in this class showed moderate to severe infection as compared with 75 and 84 per cent of those in the other two classes. It is believed that the division between trace and moderate to severe infection represents a fair separation from the standpoint of practical control in the field. The infection recorded as trace was so slight that it seems very doubtful that serious in-

fection in the field would result from the use of plants from such beds. Experience, cited previously, shows that slight infection in the bed is usually followed by slight field damage. Unfortunately it was impossible to obtain correlation between plant-bed infection and field injury in 1921 owing to the very dry weather which prevailed during the greater part of the growing season. Blackfire was almost non-existant in the fields even in those which were set from severely infested beds. Assuming that absence of seedling infection in excess of trace insures practical field control of blackfire, it may be stated that practical control was obtained in 76 per cent of cases where seed disinfection and plantbed sanitation were employed. Only 19 per cent of the beds where one or more of these measures were omitted showed similar freedom from infection. This is considered to be an excellent showing in view of the opportunities for reintroduction of the pathogenes which exist in farm practice. It seems probable that some of the moderate to severe cases in class A were due to such reintroduction or to inadequate sterilization of the canvas. In one case in this group, which has been mentioned previously, a bed covered with new canvas showed no infection while another nearby sown with the same seed but covered with old, boiled canvas showed 10 per cent seedling infection.

The possibility of the production of disease-free plants under controlled conditions and on a larger scale than that employed in our plantbed experiments was demonstrated at two of the county substations in 1921.

Two plantbeds were prepared at the Charlotte station each being 6 feet wide and 100 feet long. The soil was thoroughly steamed with an inverted pan, all seed were disinfected with formaldehyde, and new cloth was used throughout. One bed was seeded with Lizard Tail and the other with a number of varieties. No infection was found in either bed at the time of transplanting, and when examined again four days after transplantation two seedlings infected with blackfire were found in the Lizard Tail bed. It is quite possible that this was the result of contamination of the hands of the workers who had also handled plants from another bed.

The plantbed at the Chatham station was 36 feet square and on newly-cleared, burned-over land. The bed was divided with board partitions, half of it being seeded with Goldleaf and the remainder with small lots of a number of varieties. All seed were treated with formaldehyde except that of one variety in one of the small divisions. Blackfire infection developed in this division but none was found in the remainder of the bed.

The data from farm plantbeds with respect to wildfire are meagre since infection was found in only 10 of the beds inspected. Five of these cases occurred where treated seed had been used and the old canvas had been sterilized, three with treated seed and unsterilized canvas, and two with untreated seed and unsterilized canvas. Two of the beds in the first group were top dressed with manure which very probably served to introduce the pathogene. Wildfire infection was severe in one of these beds and slight in the other and both also showed severe blackfire infection. Another bed in this group was on the border of a tobacco field and presented a clear case of spread of infection from the field. No information which indicated recontamination was obtained for the other two cases. Boiled canvas was used on one of the beds and that on the other had been dipped in 1-1000 corrosive sublimate.

THE DISINFECTION OF PLANTBED CLOTH

The evidence from the field studies throws some doubt on the advisability of using old, boiled canvas in general practice. Satisfactory sterilization appears to have been realized in a majority of cases but evidence of failure occurred in others.

Neither pathogene has survived a 10-minute exposure at 124° F in laboratory tests and it would seem that satisfactory sterilization of canvas should be readily obtained by boiling. It should be borne in mind, however, that the plantbed canvas is bulky and the chance of effective work is modified by the equipment used and the care taken in seeing that all parts are exposed. It seems inadvisable to continue the use of old canvas if any question of safety exists. The cost of new cloth is slight in comparison with the potental injury to the crop from an attack of blackfire or wildfire.

In a test made with small pieces of cloth in 1921 effective sterilization was obtained by boiling for 10 minutes and also by soaking for 5 minutes in 1-500 corrosive sublimate. The cloth used was new and artificial contamination was obtained by soaking it in a suspension of **Bact. angulatum**. After drying the cloth was cut into strips, 2 x 6 feet, and these were used as covers on sections of a plantbed after having been subjected to various treatments. The occurrence of seedling infection as influenced by the various treatments was as follows:

Treatment of cloth	Per cent infection
Soaked 5 minutes, hot corrosive sublimate, 1-500	0
Soaked 5 minutes, cold corrosive sublimate, 1-500	0
Boiled 60 minutes in water	0
Boiled 10 minutes in water	0
Soaked 120 minutes, formaldehyde, 1-160	2
Unsterilized	4

THE IMPORTANCE OF FIELD SANITATION

Evidence of the overwintering of both the blackfire and wildfire pathogenes in the field, as shown by spread of infection to nearby plantbeds, has been presented in a previous section. All of the cases which we have observed occurred during a very mild winter and on land that was left unplowed until late spring. Many tobacco plants survived this winter in the field and resumed growth in the spring, and it is thought that the pathogenes may have wintered-over on the plants rather than in the soil. No clear case of the infection of plants after transplanting due to carry over in the field has been observed. On the contrary we have seen many instances where tobacco has followed tobacco in a field with no evidence of carry-over of infection. It seems, however, that a possibility of such carry-over exists. The opportunity for this would evidently be decreased by early plowing of tobacco stubble, which is also considered a good practice from the standpoint of conservation of soil fertility. As practically all of the infective material is removed with the harvested crop immediate plowing would prevent the return of such material in quantity to the soil, and would eliminate further increase of the pathogenes. Unplowed stubble soon throws out suckers which become infected and thus serve to propagate the disease during the remainder of the growing season. This provides a quantity of infective material which is eventually returned to the soil. It seems advisable, therefore, in sections where consecutive cropping with tobacco is practiced, that the stubble be plowed immediately after harvest as an additional measure of protection against blackfire and wildfire.

The same possibilities of the introduction of the pathogenes in manure which contains tobacco refuse exist in the field as in the plantbed. No stalks or other tobacco refuse should be used on the tobacco field unless the material has been subjected to the high temperatures of flue-curing.

SUMMARY

The blackfire disease occurs practically coextensively with the culture of tobacco in Virginia. In a survey in 1920 the disease was found to be present in 85 per cent of the fields inspected. Wildfire is much less prevalent than blackfire it being found in only 17 per cent of the fields.

Both diseases occur on seedlings in the plantbed, blackfire having been found in 70 per cent of the beds inspected during three seasons and wildfire in 13 per cent.

The occurrence of blackfire in the field and the severity of losses are determined in large measure by the occurrence of infection in the plantbed.

The blackfire pathogene is seed-borne and seedling infection may commonly be traced to the use of contaminated seed or of contaminated plantbed cloth, on which the pathogene may overwinter. Overwintering also occurs in tobacco refuse, unless the material has been cured at high temperatures or sterilized by other means, and also to some extent in the soil.

Severity of infection is modified greatly by rainfall and host nutrition. Raindrops are the chief agency of dissemination and excessive rainfall predisposes the host by inducing a succulent vigorous growth. The nutrition of the host as modified by fertilizers, and also by topping, determines severity of infection to a marked degree, the plant which makes the most rapid, succulent, vigorous growth being most subject to severe injury.

All varieties of tobacco grown in Virginia are apparently susceptible to blackfire, and although differences in susceptibility exist these are not of sufficient moment to make choice of varieties of practical value in control.

Complete disinfection of naturally contaminated seed has been obtained with a 15-minute soak in 1-16 formaldehyde and also with a 10-minute soak in 1-1000 corrosive sublimate. This was shown by the freedom from bacterial growth shown by such seed when plated in nutrient agar and also by the production of disease-free seedlings in plantbed tests. Seed disinfection has proved of marked value in tests under farm conditions when accompanied by proper additional sanitary measures, i. e.—location of the plantbed on new ground, use of new or sterilized cloth, avoidance of infective material.

The formaldehyde soak causes no injury to germination except in a small percentage of cases. Retarded germination, however, frequently results.

The corrosive sublimate soak causes no injury to germination, or at most a very slight one, and no retarded germination.

In addition to the use of disease-free transplants, it is advisable that field rotation be practiced, or, where this is not practicable, that the land be plowed as soon as the tobacco crop is harvested in order to suppress the further growth of plants and prevent the accumulation of infective material.

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